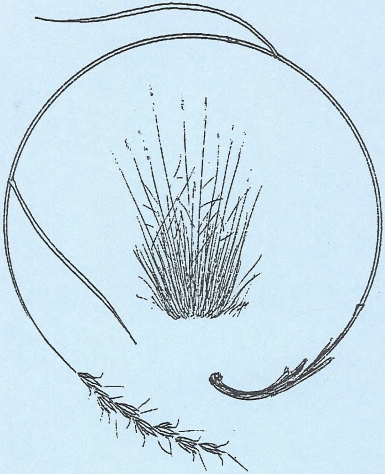
BLUEBUNCH WHEATGRASS
DEFOLIATION
EFFECTS & RECOVERY



— A Review —

by
Loren D. Anderson

REAU OF LAND MANAGEMENT
IDAHO STATE OFFICE
3380 Americana Terrace
Boise, Idaho 83706

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DEFOLIATION EFFECTS and VIGOR RECOVERY

a

REVIEW

by

Loren D. Anderson
U.S.D.I., Bureau of Land Management
Salmon, Idaho

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I. INTRODUCTION

A. General notes

Information contained in this brief literature review may be useful in discussions on range readiness, grazing systems and management of one of the west's most important grass species, bluebunch wheatgrass. This review is primarily oriented toward defoliation impacts and subsequent recovery therefrom. Of particular interest is the species' response to grazing during the growing season. This review reflects a remarkable consistency of growing season defoliation impacts regardless of precipitation or geographic location. The long-term implications of seemingly minor levels of defoliation during the growing season are also impressive.

Abstract and Management Implications sections of reports tend to be sterile and frequently misleading. The reader is encouraged to carefully read and consider the literature review. There is a risk in doing so, however. As this epistle developed, the author was forced to reconsider and even reject some long held assumptions and beliefs regarding such items as range readiness, timing and amount of utilization, time required for plant recovery, seed trampling, grazing system value, etc. Being a card carrying skeptic, it was not easy!

Most entries in the Literature Review were lifted verbatim from reports and personal communications. The Introduction, Abstract and Management Considerations sections are this author's attempt to offer some background information helpful in interpreting the review, summarize the review and to coalesce the information fragments into a management framework.

Good sources of additional information include: Response of Bluebunch Wheatgrass to Drought and Climatic Fluctuations: a Review (Ganskopp and Bedell 1979); The Ecology and Management of Bluebunch Wheatgrass (*Agropyron spicatum*): a Review (Miller et al. 1986) and the Fire Effects Information System (F.E.I.S.). The F.E.I.S. (a DG data base located at the Boise Interagency Fire Center) contains a wealth of information on taxonomy, distribution, successional status, phenology etc. in addition to the latest on fire effects.

B. Additional considerations

1. Terminology: From the onset it was apparent that terminology confounds understanding. Terms such as "heavy", "moderate" and "light" are commonly used to describe utilization levels. In the absence of further definition, however, they have little definitive meaning other than to the individual using them - they certainly cannot be accurately understood or considered by others. Even when fully defined, perceptions are extremely varied. For example, the level of utilization Mueggler (1972) defined as "extreme" would rate no more than "moderate" to some. The category Ganskopp and Bedell (1981) defined as "moderate" was so broad as to include what many would consider "light" through "extreme". Phenology descriptions

were also somewhat of a problem for this reviewer - no less than 24 different terms were encountered describing various phases within boot, flowering and seed development.

2. Clipping studies: Many of the defoliation studies included in this review were based on clipping in which all of the plant canopy above a specified level was removed. One certainly has reason to question how valid a comparison they provide with grazing. Miller (pers. comm. 1991) noted limitations of clipping studies in that indirect effects of grazing such as trampling, nutrient cycling, and energy flow cannot be addressed. Clipping should, however, be a good reflection of plant response to leaf removal and the mechanisms involved therein. Crider (1955) reported that when a portion of a plant was clipped, only the root growth below that clipping was affected. A rancher commented to this author that a cow commonly wraps its tounge around most - if not all - of the canopy at a given height and draws that material into its mouth. It was his opinion that clipping studies should give a pretty good picture of the effects of grazing defoliation on a particular plant. Strong similarity of effects between clipping and grazing studies are evident throughout this review. It is also worth noting that these clipping studies were conducted on plants the authors believed to be of excellent vigor. Effects of even one-time clipping events are striking.

3. Weather and local conditions: Studies in this review involve seven western states and British Columbia. Precipitation levels varied from McLean and Wikeem's (1985) 9.4" to Pitt's (1986) coastal 40". In spite of a wide range of latitude, longitude, precipitation and presumably soils, defoliation effects follow a remarkably uniform pattern. The consistency of response documented among many studies strongly suggests the response pattern is independent. Above or below normal precipitation appears to either dampen or exacerbate the defoliation effects but not change the pattern. With respect to drought, Holecheck et al. (1989) noted that healthy vigorous perennial grass plants with a good root system can maintain production longer into a drought and recover more quickly. Craddock and Forsling (1938) and Stoddart et al. (1975) reported that the adverse impact of drought on grass plants was proportional to grazing intensity during the growing season. A brief study conducted in the Salmon, Idaho SCS District found that, following 5 years of drought, a bluebunch wheatgrass pasture grazed only in the fall was producing 260#/acre (USDA-SCS, Salmon District 1990). An adjacent BLM spring grazed pasture of the same soils, vegetation and precipitation produced only 110# prior to the drought. Precipitation and temperature do have a large influence on phenology. For example, Pechanec et al. (1937) reported bluebunch wheatgrass phenology was advanced approximately one month during the 1934 drought in Idaho. Sauer and Uresk (1976) found bluebunch wheatgrass to flower later and longer as a result of increased precipitation. Heady (1950) noted in a Montana study that bluebunch wheatgrass growth at low elevations was favored by cooler wetter than normal conditions while at high elevations, the opposite was true.

4. Competition: Few would argue that competitive relationships play a large role in dictating floristic composition of an area, productivity of individual plants or subsequent response to, and recovery from, defoliation. Miller (pers. comm. 1991) noted that, in many studies, it is difficult to tell whether bluebunch wheatgrass response is due to a loss of leaf tissue or to changes in competitive interactions with associated plants. For whatever reason, the mind tends to default to competition being represented by some "less desireable" species. It is important to note that competition is generalized as to species and bluebunch wheatgrass can, and frequently does, compete with itself. Risser (1969) noted that yield per plant decreases with increased plant density and that widely spaced plants produce the most seed. His comments sound familiar to anyone who has done any gardening. It does help to point out, however, that there is some threshold between production for the individual plant and maximum production for the stand. In the course of this literature review, the only definitive study found specifically regarding competition and bluebunch wheatgrass was by Mueggler (1972). His findings (see review), though of significant interest, would appear nearly impossible to replicate with grazing. Replication would require grazers to differentially select all other plants within a 35" (90-cm) radius around a particular bluebunch wheatgrass plant such that they were reduced to ground level while the bluebunch plant was only reduced 50% by weight.

Heavy grazing use under various grazing systems (eg. rest-rotation) is commonly espoused in attempt to decrease selectivity and equalize competitive relationships. Heady (1984), referring to the heavy use theory, stated that he could find no data to support the concept that desirable species will recover faster than undesirable ones. Grazing schemes which encourage heavy growing season use have resulted in the destructive use of primary forages, reduced forage production and negated the benefits from otherwise valid grazing systems (Findley pers. comm. 1990, Holecheck et al. 1989, Cook and Child 1971, Trlica et al. 1977, Van Poolen and Lacey 1979, Eckert and Spencer 1987).

II. ABSTRACT

Bluebunch wheatgrass is one of the most productive, palatable and widely distributed grasses of the west. Within Idaho's Salmon BLM District, it is dominant on 15 of 32 range sites, common on 8 and exists in trace amounts on 5 others. Active growth begins with a soil temperature near 42 degrees F. with an optimum temperature range of 58-77 degrees F. Seed production is reported as being highly variable and inconsistent between years. Seed germination rates of from 53% to 85% have been obtained in the laboratory. One study reported 16% germination under field conditions. Seedling survival is frequently very poor. Two separate review authors stated they could find no literature supporting the contention that seed trampling by cattle enhances seedling establishment. The canopy of mature bluebunch wheatgrass has been found important in "funnelling" rain to the plant thereby allowing deeper water penetration beneath the plant. Plant material below about 2" (5-cm) is not considered readily accessable to cattle grazing unless the plant is pedestalled or the plant is continually regrazed.

Bluebunce wheatgrass is considered quite sensitive to grazing during the growing season because of its upright stature, slender shoots, early elevation of apical meristems to grazable height (2" (5-cm), a high ratio of reproductive to vegetative shoots and its slow regrowth potential of new leaves. Effects of growing season defoliation injury are well documented: basal area, stem numbers and both root and forage yields are reduced and mortality can be high. A consensus of authorities indicates that bluebunch wheatgrass is most vulnerable to grazing damage during the boot/early flowering stage. Less, but still significant, damage is possible during the remainder of the growing season. Defoliation to very short stubble heights during the boot stage has been reported to essentially eliminate plants within as few as three years. There was agreement that some grazing could occur prior to boot if livestock were removed before apical meristems were vulnerable. Grazing of apical meristems removes most of the actively growing tissue and greatly retards any further growth. The value of retaining a good complement of green leafy material on grazed plants was stressed by many authorities. Vigor recovery timeframes will be compressed or expanded under the influence of wet/dry climatic cycles. Vigor recovery has been found to require most of a decade, even with complete protection from grazing. Competition, both intra- and interspecific, can exert a strong influence on seedling survival and vigor recovery.

III. LITERATURE REVIEW

A. Distribution and value

Bluebunch wheatgrass, considered one of the most important native bunchgrasses of the Palouse Prairie and Intermountain Sagebrush Province, has dominated millions of acres of pristine semiarid grass and sagebrush sites, and produced more herbage than all other associated species combined (Miller et al. 1986).

Bluebunch wheatgrass occurs in 7 Bureau of Land Management pysiographic regions, 9 ecosystems and 22 Kuchler plant associations. It is characteristic of many climax or late successional communities (F.E.I.S. 1990). Bluebunch wheatgrass dominates 15 of 32 range sites in the Salmon, Idaho BLM District, is common on 8 others and shows as a trace on an additional 5.

B. Soil temperature and growth

Bluebunch wheatgrass begins active growth as soon as soils warm to 5-6 degrees C. (41-43 deg. F.) at 10-cm (4") depths with growth accelerating until the optimum of 20-25 deg. C. (58-77 deg. F.) (DePuit and Caldwell 1975) is reached, providing other environmental factors (e.g. soil moisture) remain favorable (Quinton et al. 1982).

C. Reproduction and seedling establishment

Daubenmire (1960) noted that rhizomatous individuals may prosper in "less arid" grasslands. He indicated that in eastern Washington and northern Idaho, rhizomatous bluebunch wheatgrass may colonize areas not subject to "intense aridity" during the later stages of succession. On an areal basis, the phytomass of sterile tillers far exceeds that of flowering tillers in rhizomatous populations (Daubenmire 1978). Vegetative reproduction by bluebunch wheatgrass is rarely mentioned in the literature, and thus, it is assumed to have little management implication except perhaps on a localized basis.

Seed production was found to be very poor, especially at upper elevation grassland sites, and to be extremely variable among plants and years with no apparent relationship to tiller numbers or basal areas. No individual plant consistently produced reproductive shoots. Since studies were conducted on protected sites in excellent condition, vigor of the plants should have been good [av. precip. 12"] (Quinton et al. 1982). Daubenmire (1978) studied variability in flowering of bluebunch wheatgrass in Washington and reported similar erratic results. Total number of inflorescences produced by 18 individual plants varied from a high of 784 in 1965, a low of 0 in 1968, 589 in 1969 and 173 in 1974. He indicated observations were made in essentially a climax stand which was completely protected from livestock, starting "long before" his study began.

In a one-year study, Harris (1967) found germination rates of 53% and 16% for bluebunch wheatgrass seeds under laboratory and field conditions respectively [precip. 12"-20"]. Evans and Tisdale (1972) reported 85% germination under laboratory conditions. Hanson and Stoddart (1940) obtained 76% germination using moistened blotting paper as a planting medium in petri dishes.

Young et al. (1981) noted that bluebunch wheatgrass seed is highly germinable at a wide range of temperatures, but limited moisture and excessive competition appear to be the most limiting factors hindering successful seedling establishment.

Viable bluebunch wheatgrass seeds per square meter of ground were 50 times greater (630 seeds versus 12) on a range grazed only in autumn than on an area reflecting heavy grazing. The heavily grazed range was described as being depleted in both numbers and size of climax bunchgrasses (Hanson and Stoddart 1940). These authors did not specify the season of use on the heavily grazed area. Since they specifically noted autumn use on one range and, considering the general durability of bluebunch wheatgrass grazed during quiesence, it is assumed that the heavy use occurred sometime during the growing season.

Late-season grazing following earlier deferment has been recommended for at least 75 years because seed trampling by livestock is thought to enhance production of new seedlings and thus improve the range. However, the literature does not support this (Dwyer et al. 1984). Without taking issue with the emperical observations that seedling establishment can be enhanced by livestock trampling, it must be said that quantitative studies on the subject are not available (Heady 1984).

Miller (pers. comm. 1991)and Mueggler (pers. comm. 1990) also indicated they knew of no definitive studies showing that trampling of seed by livestock promoted increased seedling establishment.

Blaisdell (1958) reported that, on an area containing as many as 200 seedlings one year, fewer than 5% survived the following growing season.

Interspecific competition in the seedling stage has been shown to retard root growth and eventually eliminate bluebunch wheatgrass seedlings (Harris and Goebel 1976).

D. Water interception

The bunchgrass structure of bluebunch allows deeper penetration of water beneath individuals due to a "funnelling" effect of the aerial parts, as the plant canopy directs light summer rain into the rooting zone of an individual plant. The ability of the aerial parts of the wheatgrass to intercept and redistribute the incident moisture may have a bearing on the capability of the species to withstand grazing and interspecies competition. It is possible that the rapid decline of bluebunch wheatgrass under heavy grazing is related to soil moisture redistribution caused by the removal of its aerial parts (Ndawula-senyimba et al. 1971).

E. Treatments (fire, spraying, brush-beating etc.)

A minimum of 20 percent cover of A. spicatum or one plant per 10 square feet is recommended for successful release of this species from competition (Plummer et al. 1965). Young and Evans (1978) suggested a rule-of-thumb that one should be able to step from one bunchgrass plant to another in order to have a reasonable expectation of positive results from fire. The primary source of A. spicatum production for several years after treatment comes from plants occupying the site before treatment (Blaisdell and Mueggler 1956, Miller et al. 1980).

F. Grazing susceptibility and regrowth

Hyder and Sneva (1963) considered plant material above 2" (5-cm) to be accessable to grazing. Stoddart (1946) felt that a 2" (5-cm) stubble height attained by clipping is probably more severe than normal grazing. Although 2" appears to be a grazable theshold height beyond which any further grazing by cattle rapidly becomes increasingly difficult, pedestalled plants are somewhat more vulnerable to being grazed to a lower height as are plants subjected to frequent and heavy regrazing. This is demonstrated by data collected within the Salmon, Idaho BLM district. Thirteen of 34 plants were grazed to a 2" (5-cm) or less stubble height on a bluebunch wheatgrass site receiving 66% utilization. Average stubble height on the site was 2.7" (6.9-cm). A site subjected to 81% utilization in the same general area averaged a stubble height of 1.7" (4.6-cm), with 32 of 40 plants having been grazed 2" (5-cm) or less. Two pedestalled plants had been reduced to 0.5" (1.3-cm).

Species such as *Poa ampla* and *Bouteloua gracilis* possess primarily culmless vegetative shoots in which the apical meristems (site of actively growing tissue) are not elevated to within reach of the grazing animal. Thus, the potential for rapid regrowth is preserved. On the other hand, species such as *Agropyron spicatum* exhibit culmed growth in the latter part of the growing season in which apical meristems are elevated as internode elongation proceeds. Thus, these critical meristems are very susceptible to removal by grazing. Any further growth must then originate from axillary buds at the base of the plant that first must be activated (Hyder 1972).

The possession of a contingent of active meristems for regrowth of productive foliage following grazing is critically important for efficient use of the carbohydrate buffer. With active meristematic tissues, regrowth following defoliation may depend on the stored carbohydrate energy source for as little as two to four days (Caldwell 1984).

Stoddart (1946) concluded that damage to bluebunch wheatgrass from herbage removal was in inverse proportion to the remaining amount of photosynthetic material exposed to sunlight.

Excepting adverse climate which is beyond man's control, the greatest single factor contributing to range depletion is excessive reduction of plant growth by grazing animals. This is accomplished through too great reduction of photosynthetic area which gradually results in starved plants (Heady 1950).

Apart from labile (available) carbon pools in the plant, recovery from defoliation depends on the quantity of remaining foliage and its photosynthetic capacity as well as the rate of development of new foliage and the photosynthetic capacity of these new leaves (Caldwell 1984).

Miller et al. (1986) also stressed the importance of green leafy material remaining on grazed plants, stating that the amount of green plant material present during various stages of phenological development greatly affects the future health and ability of the plant to compete.

Defoliation not only reduces leaf area and thus capacity to utilize moisture, but also by reducing root system activity, may limit the capacity to compete for moisture and nutrients (DePuit and Caldwell 1975).

Grazing intolerant species such as bluebunch wheatgrass, which does not curtail root growth following severe defoliation, may expend valuable carbohydrates on prolonged root growth instead of directing them to shoot system regrowth (Richards 1984). This eventually leads to substantial root mortality during the winter and growing season following defoliation (Caldwell 1984, Richards 1984).

G. Sensitivity to grazing: Timing and extent of defoliation

Bluebunch wheatgrass is considered sensitive to heavy grazing during the growing season because of its upright stature, slender shoots, early elevation of apical meristems to grazing height, and a high ratio of reproductive to vegetative shoots (Branson 1956, Harris 1967, Evans and Tisdale 1972).

Effects of defoliation injury on bluebunch wheatgrass are well documented; basal area, stem numbers and both root and forage yields are reduced and mortality can be high (Hanson and Stoddart 1940, Laycock 1967, Bleak and Keller 1973, Mueggler 1972, Caldwell et al. 1981).

Severe defoliation during the late spring when vegetative growth is proceeding rapidly and the apical meristem is being elevated has been shown to be most detrimental to *Agropyron* (Miller pers. comm. 1991, Stoddart 1946).

McLean and Wikeem (1985) [9" av. precip.] noted a mortality rate of 58% following a 1-year clipping of bluebunch wheatgrass to a 4" (10-cm) stubble on a weekly basis throughout the growing season. Mortality of 24% was recorded with plants clipped to 6" (15-cm) stubble height during the same period when compared to control plants. Mean mortality of control plants was 4%.

Pitt (1986) found an 89% reduction of bluebunch wheatgrass flowering stems following two years of defoliation to a 6" (15-cm) stubble height at boot stage. When that level of defoliation occurred at emergence from boot, flowering stem reduction increased to 96% [40" maritime precip., 210 av. frost free days].

Bluebunch wheatgrass subjected to the combined stress of heavy clipping (removal of approximately 50% of the plant's weight by clipping to a stubble height equal to 28% of the plant's height just before full emergence of the flower stalks) and full competition produced 43% less herbage and 95% fewer flower stalks the following year than were produced by unclipped plants growing under full competition. Extreme clipping (heavy clipping followed by clipping regrowth to a uniform 3" (8-cm) stubble height when control plants were at seed-in-dough stage) reduced production 72% and flower stalk numbers 97% [15.5" av. precip.] (Mueggler 1972).

Hanson and Stoddart (1940) reported a 32% shallower rooting depth and 6 times less root development for bluebunch wheatgrass plants on a heavily grazed range as compared to protected range. They empirically concluded "heavily grazed" due to climax grasses being "obviously depleted in both numbers and size". The protected range was subjected to grazing "only in the autumn after adjacent cultivated crops in the pasture had been harvested".

Branson (1956) reported that heavy clipping treatments (plants clipped to 1" (2.54-cm) at two and four-week intervals for 8 weeks) of bluebunch wheatgrass resulted in root production 100 times less than that of controls.

Stoddart (1946) found that defoliation (plants clipped to 1" (2.54-cm) and 2" (5-cm) heights on various plots) during mid to late May (heads just showing in the sheath on June 1) caused greatest mortality within one year of clipping. However, all defoliation dates at other than very early in the spring (prior to mid May) or in the fall resulted in heavy mortality. Plants not clipped after mid May during the growing season suffered no mortality. Plants clipped in the fall (September 15 - November 1) did exhibit a decline in yield the following year of 27% for plots clipped to 2" (5-cm) [16.5" av. precip.].

Sauer (1978) reported that removal of all standing dead material (clipped to crown level) from bluebunch wheatgrass prior to the growing season resulted in a 28% decrease in the weight of new leaves and culms, a 25% decrease in leaf length, but did not significantly change the number of flowering culms per clump, the height of the flowering culms or the head length. He indicated that the decrease in live weight suggests that any increase in photosynthetic rate with increased light intensity is offset by a decreased carbon dioxide rate because of greater air movement andsubsequent increased plant water stress. Miller (pers. comm. 1991) speculated that this may also support the precipitation capture theory of Ndawula-senyimba et al. (1971).

Ganskopp and Bedell (1981) studied the effects of various <u>summer-fall</u> grazing intensities on bluebunch wheatgrass in central and eastern Oregon the year following a severe drought (precip. 49% of norm.). Precipitation was 43% above normal the year of the study. They found that light use (0-25% utitilization by weight) resulted in greater growth, weight, and seed stalk numbers than for control plants. Both moderate (25%-70% utilization) and heavy (70%+ utilization) grazing had no significant effect on the same parameters as compared to control plants.

Daubenmire (1940) indicated that when bluebunch wheatgrass was clipped to ground level at the height of its growing season in late spring, most of the clipped plants succumbed, and the next year the few survivors produced only small tufts of foliage with no inflorescences. He noted, however, that grazing bluebunch wheatgrass bunches to the ground during the summer and late fall appeared to have only a slight detrimental influence on the plants [12.2" av. precip.].

Phenology data for bluebunch wheatgrass recorded at Dubois, Idaho by Blaisdell and Pechanec (1949) showed flower stalks appearing on May 23, flower heads showing June 5, and flowers in bloom on June 25. One time ground-level clipping of separate plots at five different dates starting on May 18 and ending June 28 resulted in an average 78% yield reduction the following year. An 85% reduction was noted for the clippings occurring on June 6 and June 17. Flower stalk production the year following treatments declined 91% compared to controls. Ground-level clipping on October 30 caused no yield reduction and only about a 15% flower stalk reduction the following year [10.8" av. precip.].

Caldwell (pers. comm. 1990) indicated that the boot/early flowering stage is the most biologically damaging time to graze bluebunch wheatgrass. He noted it could be grazed prior to boot stage, but livestock must be removed before apical meristems elongate. Caldwell indicated that grazing of the apical meristems will retard further plant growth as the plant will have to activate buds and generate new tillers.

Defoliation of bluebunch wheatgrass appears to suppress tiller development (Branson 1956, Caldwell et al. 1981). Competition may also be an important factor influencing tiller development following defoliation (Mueggler 1970, Caldwell and Richards 1986).

Plants can withstand utilization early in the growing season if conditions allow adequate growth after grazing. This will usually occur if animals are removed before the boot stage and there is adequate soil moisture for regrowth. Retaining only small levels of leaf area during the boot stage has the greatest negative effect on carbohydrate storage and plant vigor (Miller et al. 1986). They further indicated that if only light use occurs from boot to seed maturity, little effect on plant health results. They cautioned, however, that if more than light use was allowed, adjustments in grazing use would be required in following growing seasons to maintain plant vigor.

Miller (pers. comm. 1990) agreed that plants are very vulnerable at boot stage and recommended early grazing with livestock removal about 1.5 to 2 weeks before the boot stage. Apical meristems become vulnerable at about early boot stage on the Oregon ranges he works with. He noted that much of the forage consumed during this early grazing was previous year's growth. Turnout has been as early as February in some years. He also indicated that post growing season grazing could be initiated when plants are starting to cure and still have some green in them.

In a British Columbia study, McLean and Wikeem (1985) found the greatest injury (92% mean mortality and 94% reduction in flowering culms) was incurred under weekly defoliation treatments to a 2" (5-cm) stubble height from mid April to the end of May on a low elevation site or from early May to mid June on a higher elevation site. Treatments occurred from early boot into the flowering stage on both sites. Reduced injury (58%, 24% and 12% mortality respectively) occurred from treatments which left 4" (10-cm), 6" (15-cm) or 8" (20-cm) stubble heights. A 57% reduction in the number of flowering culms was recorded for the 4" (10-cm) stubble height. No statistical difference for flowering culm numbers was found between the 6" (15-cm) and 8" (20-cm) stubble heights and control plants. Reduced injury was also found when defoliation ceased earlier in the season (30% mortality and 57% flowering stem reduction for the period mid April to mid May) [9.4" av. precip.].

Studies in Utah and Idaho, indicated the time of greatest susceptibility to defoliation injury corresponded to the late boot or "heads emerging" stage of bluebunch wheatgrass phenology (Stoddart 1946, Blaisdell and Pechanec 1949). The boot stage (mid May) was also very susceptible to defoliation injury in a Washington study. Less injury occurred

when the clipping height was 8" (20-cm) (34% reduction in yield) compared to 4" (10-cm) (58% reduction). The lack of injury difference observed between 0-1" (0-2.5-cm) (69% yield reduction) and 4" (10-cm) stubble height was attributed to the steminess and scarcity of leaves in the first 4" (10-cm) [11" av. precip.](Wilson et al. 1960).

A south-central Washington bluebunch wheatgrass site (9" precip. Oct.-May), ungrazed for nearly 30 years was grazed to an estimated 50% utilization level two consecutive years during April and May (precise dates and phenology not given). Data obtained in year three, when no grazing was allowed, showed an 18% reduction of leaf length, 15% reduction of flower culm length and a 26% basal area decrease (Rickard et al. 1975).

Mueggler (1972) found that control plants growing in the total absence of competition within a 35" (90-cm) radius produced nearly 5 times as much herbage as control plants under full competition. His discription of full competition noted relatively continuous ground cover with little bare soil and plants competing with bluebunch wheatgrass generally more numerous in quantity and variety than usually found on drier sites. Extreme clipping (50% herbage weight removal just prior to flower stalk emergence, followed by clipping regrowth to a uniform 3" (8-cm) stubble height when controls were at seed dough stage) resulted in about a 57% decline in production with no competition and a 75% decline with full competition [15.5" av. precip.].

Skovlin (pers. comm. 1990) indicated that they had been unable to maintain bluebunch wheatgrass by grazing it at 30%-40% in early June (boot) under a deferred system in eastern Oregon.

In a Montana study, Heady (1950) concluded that clipping bluebunch wheatgrass once to 6" (15-cm) at the flowering stage was too severe a treatment to permit plants to maintain themselves. His conclusion was based on findings showing an 88% reduction in flower stalk production the year following defoliation to 6" (15-cm) as compared to control plants. He also indicated that fruiting culms were present on some plants at clipping levels below 6" (15-cm) but that they were short, spindly and produced sterile florets.

Wilson et al. (1966) concluded that bluebunch wheatgrass may be essentially eliminated from a site by grazing during the boot stage to a 1" (2.54-cm) stubble or less for three consecutive years [11" av. precip.].

In British Columbia, range readiness traditionally occurs when bluebunch wheatgrass is 6"-7" (15-18cm). This means that grazing will occur during the boot and early flowering stages when the grass is most susceptible to injury (McIlvanie 1942). Since seed production is not sufficient to maintain the grass stands under continual or improper use, grazing management becomes critical. Early spring grazing and the removal of animals would allow aftermath growth most years and a partial recovery and nutrient storage in the plants. However, data indicate that aftermath growth is variable and cannot be relied on.

The alternatives are then to graze lightly as early as possible in the current growing season for the site concerned, or to delay grazing until plants have become dormant at that site [12" av. precip.](Quinton et al. 1982).

H. Vigor recovery

Basal area, leaf length, flower stalk length, number of flower stalks and yield have all been used as criteria for evaluating bluebunch wheatgrass vigor. Of these, Mueggler (1975) concluded that flower stalk numbers used in conjunction with maximum flower stalk length was a relatively simple and reliable vigor indicator. He noted these characteristics are influenced considerably by yearly weather variations and thus, plants of "normal" vigor must be used for comparative determinations of vigor in any given year. To accommodate the natural variability of individual plants, he recommended that means from a sample of approximately 80 to 100 individuals of grazed plants be compared with those from a like sample of ungrazed plants to yield reasonably valid data. On his study area, that sample size gave a 95% probability of falling within 20% of the mean number of flower stalks. Mueggler found total herbage production somewhat inferior to flower stalks in reflecting expected trends in vigor. He noted that foliage length was by far the poorest expression of expected vigor. Eckert and Spencer (1987) concluded that measuring the basal area of bluebunch wheatgrass could be difficult in some cases. Because of its very open bunchgrass form, the amount of dead basal area could not always be distinguished from the rather large natural openings between tillers in a bunch. Basal area measurements, however, have frequently been used to successfully monitor grazing influence on bluebunch wheatgrass (Findley pers. comm. 1990, Heady 1950, Rickard et al. 1975, and others).

Mueggler (1972) found that reducing competition by clipping surrounding vegetation to ground level in a 35" (90-cm) radius around individual bluebunch wheatgrass plants, completely offset the adverse effects of heavy clipping (50% removal of herbage weight just before full flower stalk emergence). In the second year of rest, however, as competing vegetation regained its competitive status, productivity and vigor indicators of bluebunch wheatgrass were quite depressed relative to controls. This situation persisted through 5 succeeding years of rest. Caldwell and Richards (1986) questioned whether it is physiological recovery of bluebunch wheatgrass that requires so many years or the slow adjustment of competitive balance that takes much of a decade.

If low vigor bluebunch wheatgrass has any competition, vigor recovery will take a long time, even with deferred spring grazing (Caldwell pers. comm. 1990).

Plants in a depressed state of vigor following a particular defoliation regime generally require longer periods of rest for recovery. For example, bluebunch wheatgrass may require six years of nonuse for recovery from a onetime removal of 50% of the shoot system during the active growing period, even in an environment of over 17 inches precipitation (Mueggler 1975).

Bluebunch wheatgrass of low vigor may produce only two-thirds as much herbage and numbers of flower stalks as normal plants even after 5 years of protection from grazing; complete recovery can take more than 8 years [17"+ av. precip.](Mueggler 1975).

Bluebunch wheatgrass appears to be more sensitive to heavy use than Idaho fescue and recovers vigor more slowly [17"+ av. precip.] (Mueggler 1975).

Hyder and Sawyer (1951) noted an apparent change in dominanace from bluebunch wheatgrass to Idaho fescue on areas subjected to heavy grazing ("heavy" was not defined).

Findley (pers. comm. 1990), working with bluebunch wheatgrass ranges in eastern Oregon, indicated further decline in bluebunch wheatgrass vigor under systems allowing heavy spring use (50%+ utilization at various use periods from early leaf to seed set) one year followed by complete rest the next year. Vigor decline was documented in terms of decreased basal area and seed stalk production [10" av. precip.].

Basal-area cover of bluebunch wheatgrass, Idaho fescue, and squirreltail did not increase when plants were growing in competition with big sagebrush and when grazed heavily (65%) during the growing season 1 year out of 7. On an area where sagebrush canopy cover had been reduced to 1%, heavy grazing during the growing season 3 out of 9 years was implicated as the primary factor restricting the growth and reproduction of understory grasses [10"-14" precip.](Eckert and Spencer 1987).

Skovlin (pers. comm. 1990) stated that by grazing one year at "seed show" and the following year at "seed set" to about 35% utilization, they had been able to maintain and improve vigor of bluebunch wheatgrass over the long term.

Yeo et al. (1990) reported a 42% increase in canopy coverage of bluebunch wheatgrass over an eight year period in a Wyoming big sagebrush/bluebunch wheatgrass type in east-central Idaho. Increase in canopy cover occurred following delay of grazing until the seed ripening stage (Yeo, pers. comm. 1990), grazing only once every 3 years and concurrent with a naturally occurring 62% density reduction (.13 stems/sq. ft. to .04 stems/sq. ft.) of sagebrush. No increase in frequency of bluebunch wheatgrass was noted. Prior to the period of vegetation change, the site was grazed annually during May, the actively growing period for bluebunch wheatgrass [4.2" precip. Oct.-May].

IV. MANAGEMENT CONSIDERATIONS

A. Timing and intensity of use

1. Growing season: Bluebunch wheatgrass has been shown to be very sensitive to utilization during the active growing season. The period of greatest potential for defoliation damage appears to be from just prior to the boot stage through flowering.

Preserving apical meristems and retaining a good complement of leafage are critical to maintaining continued viability of bluebunch wheatgrass. Utilization levels of 30%-40% under deferred grazing systems have been found too severe as has retaining stubble heights of 6"-8". Onetime growing season utilization levels of 50%+ (as commonly occurs under a number of grazing systems) have been shown to cause very long term (upwards of a decade) significant reductions in vigor and productivity, even if followed by complete protection.

Early spring grazing is tolerable where the bulk of the forage is previous year's growth and livestock are removed 1.5-2 weeks prior to the boot stage.

2. Non growing season: Grazing may be initiated without adverse effects when plants have begun to cure but still have some green in them. Defoliation to stubble heights of 2" during dormancy is not likely to cause mortality, although a yield reduction of about 25% may be incurred the following year.

B. Recovery

1. Individual plants: Rate of recovery from defoliation will depend on the plant's total non-structural carbohydrate (TNC) reserves, its photosynthetic capacity during the active growing season, the amount of apical mersitems remaining, the degree of competition and available soil moisture. The argument that utilization levels during the growing season are irrelevant as long as good soil moisture conditions can be expected for regrowth is erroneous. Recovery of full forage production and reproductive capacity for healthy plants subjected to onetime heavy utilization (50%+) during the growing season may be in excess of 8 years under the best of management or protection. The presence or absence of additive stresses associated with site characteristics (eg. marginal soils), drought, competition, and other defoliators such as grasshoppers may strongly influence recovery periods.

2. Range: Bluebunch wheatgrass range recovery is strongly limited by the poor competitive ability of the plants and their seedlings, erratic production of seed (even from vigorous plants), near nonexistent seed production from low vigor plants, and frequently poor seedling establishment and/or survival. Under the most prudent management, realistic time-frames for meeting objectives to increase range production or improve undesirable ecological range condition will be most of a decade or longer.

C. Monitoring

1. Vigor: Flower stalk numbers in conjunction with maximum flower stalk length is apparently the most sensitive vigor indicator for bluebunch wheatgrass. Comparisons must be made with similar measurements of vigorous plants and sample sizes must be large enough to accommodate inherent variability (see review, Mueggler 1975). Yield and basal area comparisons also have utility for monitoring vigor. Leaf length has not been found a reliable indicator of vigor.

Although utilization during the growing season may be "light" on average, individual plants will likely sustain excessive use. Recording plants in this latter category will provide an index of future trend by identifying plants vulnerable to declining vigor or mortality.

2. Ecological range condition: Very long time periods (upwards of a decade or more) will likely be required to detect upward trend using studies dependent on plant numbers (e.g. nested plot frequency). Downward trends, however, may be detectable in as few as one or two years, depending on the amount and timing of defoliation and resultant mortality.

C. Grazing management

It is evident that avoiding defoliation during the active growing season is essential if enhancement of vigor (i.e. yield and reproduction) and improvement of condition class are objectives. Although some "light" grazing may be allowed during the active growing season, tolerable utilization levels are so low (see above) and the room for error so great that any grazing would appear impractical, if not risky. Livestock grazing should be based on plant phenology rather than particular calander dates.

The belief that range improvement will occur after one or two years of rest following a single season of more than "light" use during the growing season is erroneous. The long period of protection required for healthy vigorous plants to recover from a single 50% defoliation makes one wonder if any grazing system involving use from the pre-boot stage through flowering can be devised which will allow for range improvement. During the seed development stage there appears to be a little more management flexibility. Any use during this period, however, would require careful monitoring to assure the potential for increased vigor and production was not lost.

Encouraging heavy use (often promoted under rest-rotation and deferred systems) during the growing season in an attempt to reduce effects of competition is self-defeating. Results indicate primary forages are subjected to destructive levels of use and the attendant loss of vigor and yield. No evidence is available to indicate primary forages recover faster than their competitors.

No definitive evidence could be found to support the contention that seed trampling increases seedling establishment.

V. SUMMARY

Bluebunch wheatgrass is extremely sensitive to defoliation during the growing season. This sensitivity is manifested in long-term reductions in root mass, basal area, seed production and biomass production and in increased mortality. Loss of vigor and biomass production and greater mortality can easily result from improper grazing. Recovery of low vigor or otherwise depleted ranges requires an investment of time and adjustment of grazing strategies to avoid growing season use. Prudent grazing management will result in substantial increases in bluebunch wheatgrass production and general range health.

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